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NUCLEAR OPERATION: PROJECT GASBUGGY

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NUCLEAR OPERATION: PROJECT GASBUGGY

The preparation for an experiment like Gasbuggy begins well in advance of the actual detonation. This paper describes the nuclear-operation portion of such an experiment.

PROJECT DEVELOPMENT

Once a company, a group of companies, or a public agency has conceived a new application for nuclear explosives, the first step in its development is a feasibility study. The participants in the feasibility study include, in addition to the originators of the idea, the Atomic Energy Commission and perhaps other companies, agencies, and the Lawrence Radiation Laboratory. The feasibility study for Project Gasbuggy was conducted by the El Paso Natural Gas Company, the U. S. Bureau of Mines, and the AEC, with some assistance from LRL. The study included a discussion of the potential product recovery for the application, a description of the project site, a prediction of the expected nuclear effects, and a preliminary evaluation of hazards. (For the second and subsequent projects in a particular area of application, a feasibility study is not made.) If the results of the feasibility study look promising, a technical concept is developed, setting down the objectives of the project and the measurements that would make a technically meaningful experiment.

The feasibility study and the technical concept are further studied by the participating organizations; if it is decided to proceed with the project, a proposal is submitted to the AEC, and operational plans are developed by the Laboratory Test Director and the Nevada Operations Office Test Manager so that project budgets can be prepared. If satisfactory fiscal arrangements can be made and a contract is negotiated between the Government and any industrial partner, the project may proceed toward execution.

The Project Gasbuggy contract was signed between El Paso Natural Gas Company and the U. S. Government, represented by the AEC and the Department of the Interior, on January 31, 1967.

PLANNING AND DESIGN

EXPLOSIVE SELECTION

An important part of preparing the Test Director's Operational Plan is the selection of an explosive. It is not always possible to select an explosive that will have the same yield assumed in the feasibility study; however, an explosive is chosen that will most nearly produce the desired effects.

Important considerations in selecting an explosive are desired yield, emplacement environment, minimum dimensions, reliability, and compatibility of nuclear debris with ultimate product. Such environmental conditions as the temperature and pressure of the emplacement location bear on the selection. We select an explosive of the minimum size consistent with the other requirements so that costs of construction and occupancy time for the hole, emplacement, and stemming are kept to a minimum. As far as possible, we avoid using experimental or developmental explosives and ancillary systems; rather, we try to use explosives which have been developed and engineered for field use and tested for reliability.

EXPLOSIVE CANISTER

When the explosive has been selected, the next step is to design a canister. In many Plowshare underground-engineering applications, the in-situ conditions are hostile enough to require some kind of environmental control beyond that provided by a simple protective can. For example, the Gasbuggy downhole temperature is 131°F and the gas-reservoir pressure is 1250 psia. For this project it is desirable to keep the temperature of the explosive below 100°F and to isolate the explosive and the electronic equipment from the reservoir pressure.

The Gasbuggy canister is substantially different from those used in applications requiring little or no pressure resistance. Since the emplacement hole is cased, we do not expect that the canister will be subjected to reservoir pressure; however, the casing may leak, and the bottom pressure could rise to that of the reservoir after the hole is stemmed. In addition to the explosive, the canister contains auxiliary equipment for monitoring critical functions and detonating the explosive.

The design of the environmental-control module is more complex than that of the canister, and is dictated by the severity of the in situ conditions. The Gasbuggy module has refrigerator units that are completely contained below surface, and the heat is dissipated by conduction through a fluid to the surrounding environment. In other programs we have used different cooling systems: a standard refrigerator type, in which coolant is circulated from the surface; or thermistor banks, whereby the heat is pumped in stages from the explosive space to the outside environment.

Once the explosive canister and environmental-control module have been fabricated, they are tested in a chamber for pressure integrity and temperature

regulation. After a static pressure test, the chamber is cycled to determine how the canister and module perform under other potential conditions.

Some possible Plowshare underground-engineering projects need no pressure canister or environmental-control module; others may require one or both, of much more sophisticated design.

CABLE

In parallel with the design of the canister and the environmental-control module, we also prepare specifications and designs for the cable that will connect the canister and module to the electrical equipment on the surface. In addition to the existing temperature and pressure, the cables must also survive the transient temperature due to the heat of hydration of the grout that is used in stemming. Samples of the cable are tested for both electrical and mechanical reliability.

Figures 1 and 2 show the subsurface arming and firing cable being used on Gasbuggy.

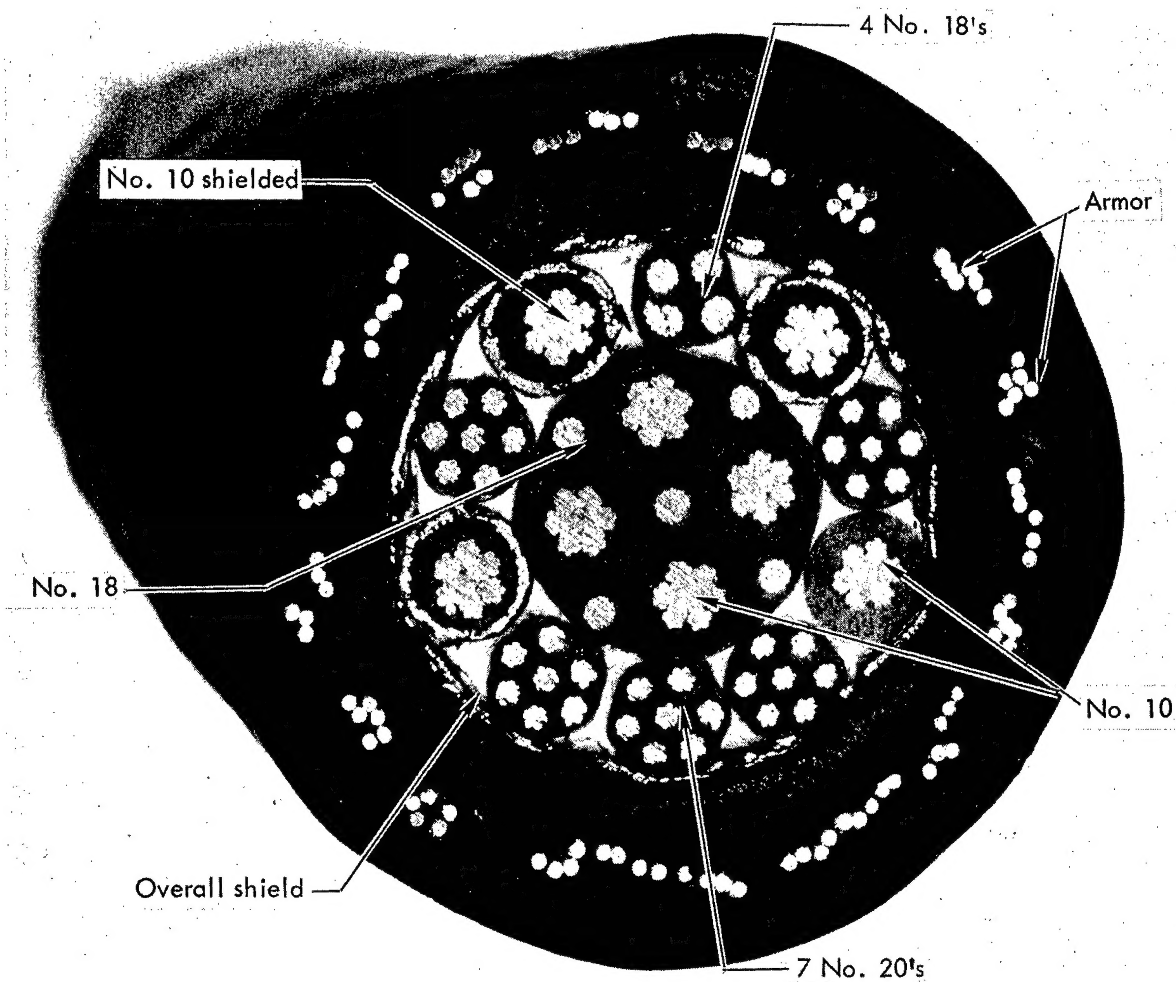

Fig. 1. Cross section of Gasbuggy arming and firing cable. The outer conducting ring contains one cable with four No. 18 conductors; five with seven No. 20's; three No. 10's, shielded; and one No. 10 unshielded. The inner group contains four No. 10's and five No. 18's.

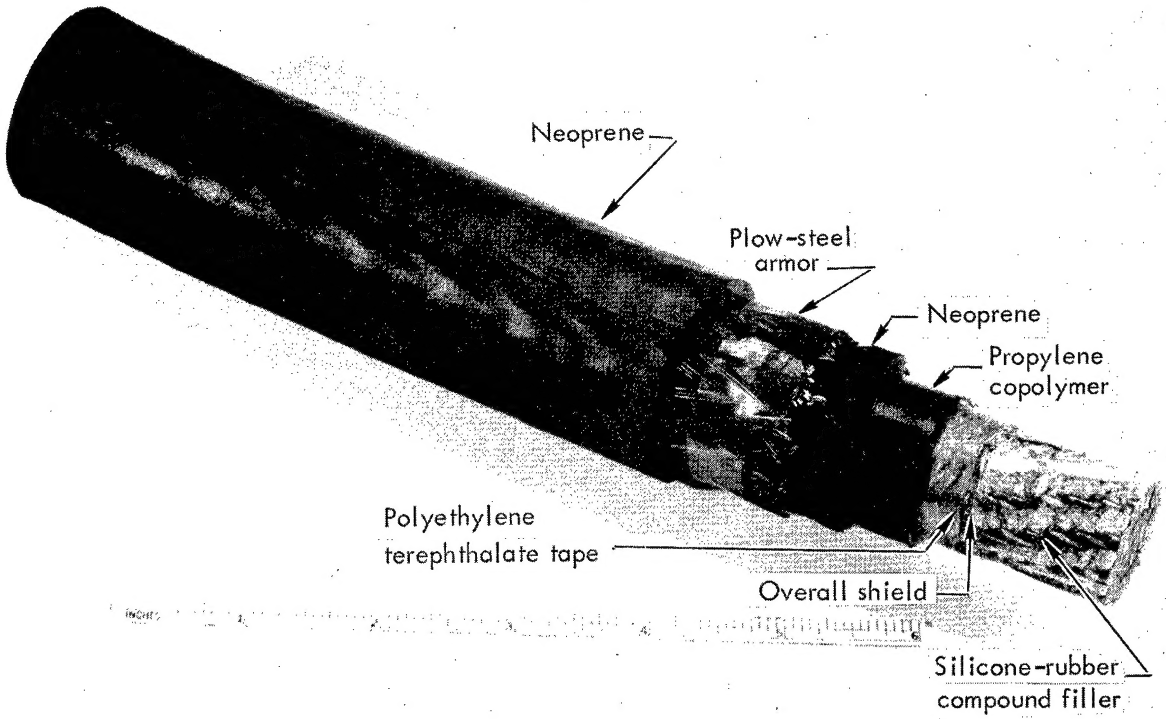

Fig. 2. Cutaway view of Gasbuggy arming and firing cable.

ON-SITE ACTIVITIES

CONSTRUCTION

Meanwhile, the emplacement hole is being constructed and the test site prepared. The construction of the hole is monitored closely not only to ensure satisfactory emplacement, but also to ensure, among other things, a good material balance while cementing the casing to preclude the escape of radioactivity through the annulus at shot time.

Areas are cleared and leveled at the control point (CP) and at surface ground zero (SGZ) for programmatic trailers, and at the recording-trailer park (RTP) for trailers that house the electronic recording equipment. At other locations we install radiation monitors, meteorological stations, and television and photographic cameras to record surface motion. Trails are cleared between all these locations for the installation of electrical cables.

Coaxial cable for transmitting high-frequency content data is laid from the instrument locations around SGZ to the RTP, approximately half a mile away. Coaxial cable is also laid between SGZ and the CP for television. Multiconductor cable connects all locations for the timing,

firing, system-monitoring, and safety-program signals.

Special structures, such as the explosive-assembly building, are erected to house the explosive until it is emplaced and to house the SGZ ends of the cables that go to the explosive, to the environmental-control module, and to the CP. A hole in the foundation of the assembly building accommodates the explosive canister and environmental-control module in a vertical position.

During the construction, preshot technical measurements, such as those necessary for evaluation of reservoir characteristics, are underway.

EXPLOSIVE DELIVERY

When construction has been completed and preliminary cable checks made, the explosive is delivered to SGZ. The AEC is responsible for moving the explosive from the fabricators to the site. It is transported in a specially built truck and escorted by security and emergency equipment. Once in the assembly building, the explosive is given an external physical check and then radiographed. If anything is found out of order, the explosive will be returned and replaced by a backup explosive.

DRY RUNS

After the explosive is installed in the canister, the firing and monitoring systems are checked, and dry runs commence. During a dry run we go through the countdown sequence just as we would for the actual detonation, and we check for proper operation of all electrical systems.

In the RTP, engineers use the dry runs to check the systems which will record the phenomenological measurement data from instruments in the emplacement and satellite holes. They are able to simulate the signals they expect and make adjustments for proper recording on tape recorders or oscilloscopes.

In the complex of trailers at the CP is a timing and firing (T&F) trailer which houses the electronic gear that originates the timing signals sent to the experimenters during dry runs and at detonation and where all the technical program monitors are displayed. The timing signals are precisely related to world time, maintained by the Bureau of Standards. The countdown is started by manual switch; once started, it automatically steps through the count to zero.

Safety-program information received from remote-reading radiation sensors, surface-surveillance television, meteorological units, and subsurface listening geophones is recorded and displayed in another trailer at the CP. These units are also checked during the dry runs.

In this way, during dry runs, the explosive and the recording and safety-program systems are checked many times for proper operation.

PRE-ARMING

When we are satisfied that everything is ready, we pre-arm, making the final electrical connections to the explosive after locking out the surface end of the firing cable to eliminate the possibility of inadvertent detonation.

After pre-arming is completed, the explosive and environmental-control module are placed and sealed in their pressure-tight outer canisters. Then we are ready to emplace the explosive.

EMPLACEMENT

The downhole operation of emplacement for Gasbuggy will start at D-2 weeks. The roof of the explosive-assembly building is removed, and the assembled explosive canister and environmental-control module is lifted from the building by a mobile crane, transferred to the emplacement hole, and secured a few feet below the surface. The combined Gasbuggy downhole package is 17-1/2 in. in diameter and 16 ft long, and weighs approximately 2000 lb.

The drill rig used to lower the explosive is now skidded into position over the emplacement hole. The explosive is emplaced with standard oil-field well casing. The casing is positioned on one side of the rig, and storage reels of downhole electrical cable are on the opposite side. An idler reel under the rig floor facilitates a smooth transition of the cables from a horizontal to a vertical position. Emplacement proceeds as the successive pieces of well casing are picked up, threaded, and lowered.

The cables are fastened to the outside of the well casing with Kellems grips for support. To prevent abrasion, they are taped to the well casing between grip locations, and centralizers are used to prevent crushing of the cables between the well casing and hole casing.

When lowering is completed, the casing is supported by a special hanger with provision for egress of the downhole cables.

Other methods have been used for explosive emplacement, such as lowering the assembly on a continuous length of wire rope wound on a power winch, or successively lowering short pendants of wire rope with a mobile crane. We anticipate developing a driven-capstan system capable of lowering heavier weights on a continuous line into an uncased, fluid-filled emplacement hole.

After a bottom-of-the-hole electrical check, the process of stemming starts.

Figure 3 depicts the explosive emplacement, the shock instrumentation grouted in place, and the locations of the RTP and CP at the experimental site.

STEMMING

The first 400 ft of well casing is slotted to facilitate grout stemming. Grout tubing is run inside the well casing so that it does not damage the cables taped to the outside.

The stemming is done in three sections. The first is 100 ft of specially compounded, medium-matching grout, which enables us to make the phenomenology measurements. The second stage of grout is approximately 1200 ft deep. Both of these grouts are designed to minimize the temperature rise that results from the heat of hydration.

The first two stages of grouting fill both the annulus and the inside of the well casing to 3000 ft below the surface. The balance, except for the top 50 ft of annular volume, is filled with sand. A polymer which sets up from a liquid to a

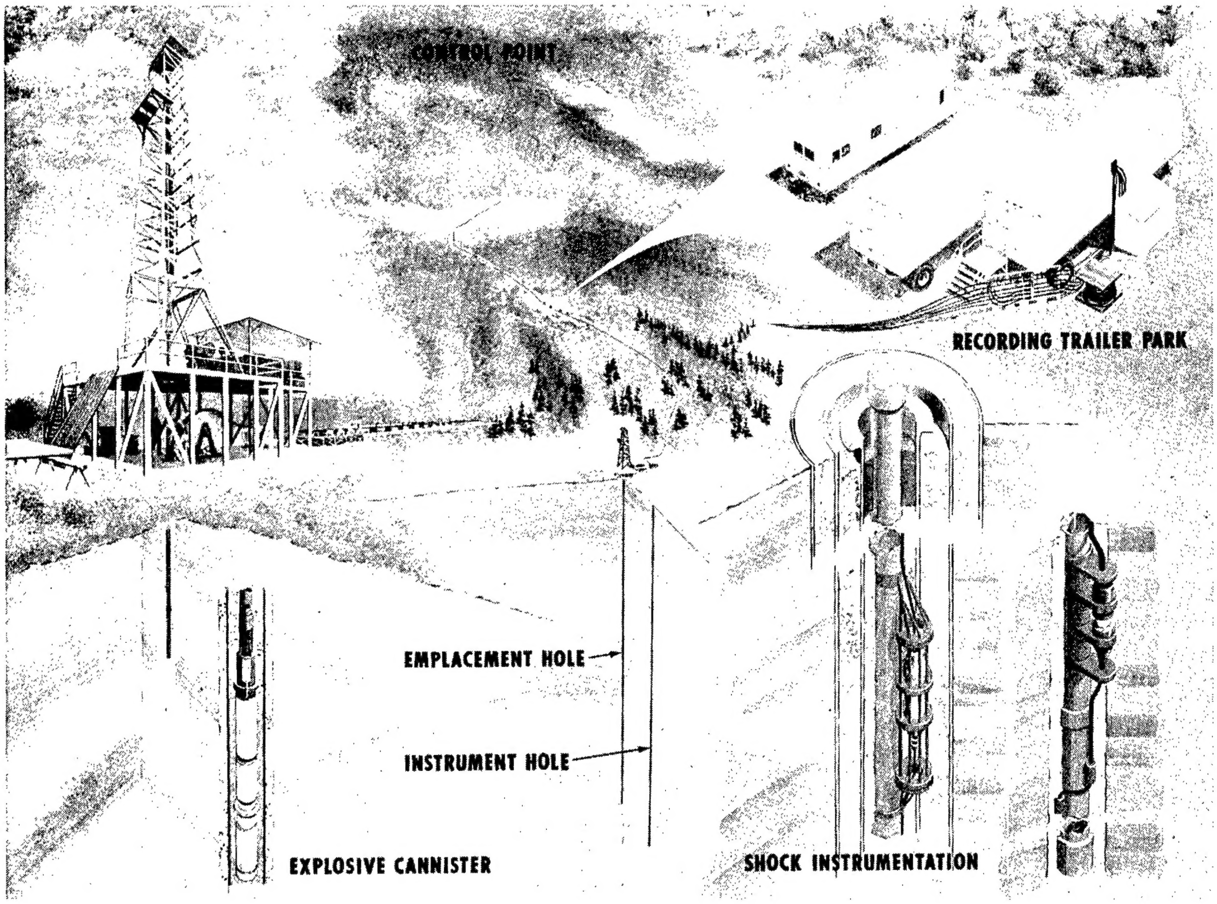

Fig. 3. Gasbuggy test site and emplacement hole.

consistency like vulcanized rubber is pumped into the remaining 50 ft of annular space.

As a backup to the stemming, the top of the well casing is capped with a pressure-sealing flange and plate, and the well casing is sealed to the hole casing by a special pressure-tight spool piece with a port on one side through which cables run. A remotely controlled closure mechanism enables us to cut the cables and make a seal if necessary after the shot. Satellite holes and nearby gas wells that could come under the influence of the explosion are also stemmed.

These precautions are taken so that if radioactivity were near the surface it would be contained and not leaked to the environs.

ARMING AND DETONATION

Once all is in readiness for the detonation, the Test Manager convenes his Scientific Advisory Panel, on which there are experts in meteorology, radiation safety, and operational control. The Panel reviews the situation, and, if

they determine that we can proceed with the detonation, the area is cleared of all personnel, and we arm the explosive.

With the T&F trailer electrical systems locked out, final connections between the downhole arming and firing cable and the surface cable to the T&F trailer are made in the explosive-assembly building. This arming operation usually takes only an hour.

If conditions are still "go" at the appropriate time, the Test Director is given permission to proceed with the countdown. It is possible at any time during the countdown to override it manually and stop it in case of failure in one of the systems or because of operational considerations. Once the detonation has occurred, safety-program displays are monitored carefully until we are satisfied that the chimneying process subsequent to the detonation has ceased and that there are no dangerous levels of radioactivity.

RE-ENTRY

Although the chimney is not expected to come anywhere near the surface, we are always reluctant to send anyone near SGZ until we are sure that the chimneying process has ceased.

The remote-reading radiation sensors are located around SGZ, beneath the surface in the stemming material, at SGZ, in the RTP, and at other critical locations to enable us to determine if radiation is present.

SGZ is first re-entered by Hazards Control personnel equipped for protection against radioactivity. They survey the area with portable instruments as a check on the remote reading system. If they do not detect dangerous levels of radioactivity, the area is opened to the technical-program personnel to begin the recovery of data.

Once technical data have been recovered, the area is opened to personnel who wish to make other, more leisurely examinations. Not until after all data that are desired by project participants have been obtained will the area be opened to other personnel or prepared for postshot drilling activities.

The nuclear operation I have outlined here is fairly simple and straightforward compared to some of the more complex activities that we have undertaken elsewhere; however, it is unique here in its application. We will operate with a minimum of hazard to personnel both on and off the site while trying to gain maximum advantage from the new application.

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